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INAUGURAL DISSERTATION

ON THE

Chemical Properties of Atmospheric Air:

SUBMITTED TO THE EXAMINATION OF THE

REV. JOHN EWING, S. T. P. *PROVOST*,

THE

TRUSTEES AND MEDICAL PROFESSORS

OF THE

UNIVERSITY OF PENNSYLVANIA:

FOR A DEGREE OF DOCTOR OF MEDICINE, ON THE
TWELFTH DAY OF MAY, 1791.

BY WILLIAM R. COZENS, OF NEW-JERSEY, MEMBER
OF THE PHILADELPHIA MEDICAL SOCIETY.

"Phoebe, fave novus ingreditur tua templa sacerdos."

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TO

JONATHAN ELMER, M. D.

AND

THE REV. ANDREW HUNTER, A. M.

THIS

DISSERTATION

IS INSCRIBED,

WITH ALL DUE DEFERENCE

AND RESPECT,

BY THEIR MUCH OBLIGED

FRIEND AND PUPIL,

THE AUTHOR.

PREFACE.

THE laws of the Univerſity of Pennſylvania reſpecting a Medical Education, have required among other things, that every candidate for a degree of Doctor of Medicine, ſhall publiſh a Theſis, written in the Latin or Engliſh language, at his own option.

FORMERLY the Latin language was conſidered the moſt proper medium for all ſuch productions, as it was expected that almoſt every eſſay would be read by people of different nations. But as I have not the vanity to think that this Theſis will circulate where the Engliſh language is unknown, I have choſen it as a vehicle to communicate my ideas to the world, for which I have the authority of many eminent literary characters, which I hope will be a ſufficient excuſe for, and ſcreen me from, the imputation of ſingularity.

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INAUGURAL DISSERTATION.

THE preſervation of our health, and the cure of diſeaſes, as well as the explanation of many chemical proceſſes, being ſo much influenced by an accurate knowledge of the chemical properties of the atmoſphere, as alſo of inflammable and fixed air, called by M. Lavoiſier hydrogen and carbonic acid gas, I conſider ſufficiently apologies for my making the inveſtigation of them the ſubject of an inaugural diſſertation; in which, if I differ from the moſt common received opinion, I hope I ſhall be excuſed for purſuing that which appears to me beſt eſtabliſhed by facts and experiments. And if I ſhould not be able to add to the preſent knowledge of the ſubject, ſo far exhauſted by the intenſe labours of ſo many eminent authors, I hope my well meant endeavour will not be

be conſtrued into preſumption. Under theſe conſiderations, I ſhall proceed with the utmoſt diffidence to arrange the ſubject under different Sections.

SECT. 1ſt. I ſhall make ſome obſervations on the atmoſphere, and its component parts. 2d. I ſhall endeavour to explain the nature and properties of hydrogen gas. 3d. I ſhall treat of carbonic acid gas.

SECT. I.

Obſervations on the atmoſphere and its component parts.

THE atmoſphere, which encircles our globe, and which we breathe, was formerly conſidered to be a ſimple homogeneous maſs; but by the inveſtigation and experiments of philoſophers, it has been diſcovered to conſiſt of two kinds of air, eſſentially different from each other, each of which may be eaſily obtained in a ſeparate ſtate by many artificial as well as by many natural proceſſes; and when analyſed, are ſuppoſed

ſuppoſed by many to be ſimple elementary bodies. But it is now clearly demonſtrated by chemical analyſes, that all aeriform fluids are compound bodies, compoſed of a baſe more or leſs ſolid, united with a certain ſubtle penetrating ſubſtance, ſuppoſed to be the matter of heat or elementary fire, called by M. Lavoiſier, *caloric:* That caloric, when combined with the baſe, keeps it in a ſtate of ſolution, and reduces it into the form of vapour or elaſtic fluid, in which ſtate it poſſeſſes the common properties of air: That theſe component parts may be decompoſed and ſeparated from each other by combination with other bodies; and when thus decompoſed, are found to poſſeſs properties very different from thoſe they poſſeſſed in a ſtate of combination. The different airs compoſing the atmoſphere, are pure and mephitic air, called by M. Lavoiſier, oxygen and azotic gas, which are always found to exiſt formally in it; and which are commonly combined in the proportion of twenty-ſeven parts of oxygen gas and ſeventy-three of azotic gas in an hundred parts of atmoſpheric air. This proportion, however, is found to vary in

different ſtates of the atmoſphere; by a knowledge of which at any given time, and the properties of theſe airs in a ſeparate ſtate, we readily aſcertain the particular properties of the atmoſphere at that time, which in a great meaſure influences animal health according as it is more or leſs pure, which depends on its ſuperabounding either with oxygen or azotic gas.

That component part of the atmoſphere, called by Mr Lavoiſier *oxygen gas*, is proven by the experiments of philoſophers to be compoſed of a peculiar baſe combined with caloric, or the matter of heat which keeps it in its aeriform ſtate, and is the only fluid capable of ſupporting combuſtion and the reſpiration of animals; which is proven from its being three times as effectual as atmoſpheric air in theſe proceſſes; that is to ſay, an animal will breath three times as long in it as in common atmoſpheric air, and a body which requires four cubic inches of atmoſpheric air to be entirely burnt, will require no more than one cubic inch of it for the ſame purpoſe; which is alſo a proof, that the oxygen gas con-

contained in the atmoſphere in its common ſtate, does not exceed the proportion of one-fourth of the common maſs. In the proceſs of combuſtion the oxygen gas is decompoſed, the caloric or matter of fire being ſeparated and diſſipated, while the baſe unites and becomes fixed in the body which is burned; and in this manner the whole theory of combuſtion is explained by thoſe who deny the exiſtence of phlogiſton, or the principle of inflammability in bodies. The property and proportion of oxygen gas in the atmoſphere, clearly explains why only about one-fourth of a given quantity of common atmoſpheric air is abſorbed during combuſtion, and why the proceſs of combuſtion is effected more ſlowly, and with the diſengagement of a leſs quantity of light and heat in atmoſpheric air than in oxygen gas; and alſo why air, which has ſerved the purpoſes of combuſtion and animal reſpiration, will no longer ſupport animal life or maintain combuſtion. This kind of air is poſſeſſed of ſome more of the properties of common atmoſpheric air in an eminent degree, beſides thoſe which have been mentioned; it exceeds it a little in its ſpecific gravity

gravity, the proportion between it and common atmoſpheric air being that of 168 to 152. On introducing a lighted candle into it, the flame not only grows larger but becomes exceedingly bright, and when it is very pure the candle burns with a decrepitation as if it contained ſome combuſtible matter, at the ſame time the wax or tallow waſtes in a ſurpriſing manner; the heat of the flame is in proportion to the light. If we fill a bladder of oxygen gas, and then faſten to its neck a glaſs tube, whoſe aperture is drawn to a fine point, the fluid if driven out by preſſing the bladder, will augment the heat of the candle to ſuch a degree, that if any ſmall pieces of metal placed on a bit of charcoal be held in the apex of the flame, they will be almoſt inſtantly fuſed, even platina may by this means be fuſed; and in a large fire there is no doubt that the effects of burning mirrors might be equalled. Oxygen, or the baſis of oxygen gas, conſtitutes one of the component parts of all acid bodies, from which property it has derived its appellation; and the difference obſerveable in acids is ſuppoſed to depend entirely on the different kinds of matter

ter with which this principle is combined in forming thoſe acids. Oxygen combined with metals by means of heat or any other way, deſtroys their metallic quality, and converts them into calces, which equals the weight of the metal employed, and elaſtic fluid abſorbed in the proceſs; which ſatisfactorily proves that the calcination of theſe ſubſtances does not depend upon the ſeparation of a ſubſtance, but upon the addition of oxygen gas, as the weight is increaſed; and what further corroborates this opinion is, that they may be again reduced to their metallic form by ſeparating this baſis from them. But the moſt curious and extraordinary property of this aerial baſis is, that it conſtitutes one of the component parts of common water; for if it be united with hydrogen by combuſtion, in the proportion of 85 parts of oxygen to 15 parts of hydrogen, common water will be produced, equal in weight to the two aerial fluids employed in the proceſs. This theory is farther corroborated from obtaining hydrogen gas by decompoſing water, by paſſing it through an iron tube, heated red hot at one end, and kept cool at the other, for the purpoſe

poſe of applying a bladder, in which the hydrogen gas will be collected, and the oxygen gas will be abſorbed by the metal in the inſide of the tube, which will be found calcined. Many of the proceſſes of nature and art alter the ſtate of the atmoſphere, by encreaſing or by diminiſhing the proportion of oxygen gas in it. Thus (as has already been ſhown) the combuſtion of all inflammable bodies, and the reſpiration of animals, by the abſorption of the oxygen continually diminiſhing its quantity in a given proportion of the atmoſphere, gradually rendering it effete and unfit for farther reſpiration and combuſtion, as happens frequently in crowded gaols, hoſpitals and ſhips. On the contrary, other bodies, as the leaves of vegetables when acted upon by the rays of the ſun, poſſeſs the property of decompoſing water; and the hydrogen gas being abſorbed by the leaves, the oxygen which entered into the compoſition of the water is diſengaged, and thereby renews and purifies the atmoſphere, and in this manner it is, that the proper proportion of the atmoſpheric air is kept up by vegetation. Thus we ſee, that one kingdom

dom affords the principle of exiſtence to the other, and death to itſelf. Hence it clearly appears, that if benign Nature had not provided for the preſervation of this equilibrium, both muſt ſoon have periſhed.

Azotic gas, as obſerved above, is one of the component parts of the atmoſphere, into the compoſition of which it enters in the proportion of 73 of azotic gas to twenty-ſeven parts of Oxygen gas in an hundred parts of atmoſpheric air. It is conſidered as a compound body, as well as all the others compoſed of a peculiar baſe, called by Lavoiſier, *azote;* from whence its name, combined with caloric, which fuſes and reduces it to its aeriform elaſtic ſtate, in which it exiſts ready formed in the atmoſphere, and is developed in proportion as the oxygen gas is abſorbed or diſſipated by combuſtion or animal reſpiration. This was proved by an experiment of M. Lavoiſier, who introduced four ounces of mercury to fifty cubic inches of common air; who propoſed to calcine the metal by keeping it twelve days in a heat almoſt equal to that which is neceſſary to make it boil: after the expiration

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of the appointed time, forty five grains of the precipitate per ſe were formed, and the air in the veſſel was diminiſhed by about one-ſixth of its volume. In this ſtate it inſtantly extinguiſhed candles, and killed animals immerſed in it, and it did not precipitate lime water; which contradicts the opinion of thoſe philoſophers who ſuppoſe, that in the act of combuſtion phlogiſton is admitted into the air, which uniting with it, forms the aerial acid which renders it noxious to animals and unfit for combuſtion. On diſtilling the precipitate produced, about as much oxygen gas was obtained as had been loſt by the common air in the calcination, and by recombining this with the noxious air left in the veſſel, he reproduced a fluid nearly of the ſame quality as common atmoſpheric air. Hence he draws the following concluſions; firſt, that five-ſixths of the air we breathe is incapable of ſupporting the reſpiration of animals, or the combuſtion of inflammable bodies. Secondly, that the ſurplus, or only one-ſixth of the volume of atmoſpherical air, is reſpirable. Thirdly, that in the calcination of mercury this metallic ſub-

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ſtance abſorbs the ſalubrious parts, leaving only the noxious portion. Fourthly, That by reuniting thoſe two portions we can reproduce air ſimilar to that of the atmoſphere. Many important diſcoveries have lately been made reſpecting the nature of this air. Its weight to that of the atmoſpheric air is as 985 to 1000; and by experiments it is proven, that three parts of it, and ſeven parts of oxygen gas, expoſed to the action of electric fluid, produces the nitrous acid: this diſcovery clearly explains the theory of the formation of the nitrous acid in the atmoſphere, and the remarkable fulminating properties of that ſingular fluid; when combined in the proportion of five parts of it with one part of hydrogen gas, it forms volatile alkali, as all animal and ſome vegetable ſubſtances contain azotic gas; it is in conſequence of this combination, effected by the action of fire or putrefaction, that volatile alkali is obtained from them. Neither water, earth, nor acids, have any ſenſible action on this air. Theſe remarkable properties of azotic gas, are more particularly entitled to the attention of phyſicians, as they throw great

light on the medical properties of air, diſcover the cauſe of its ſalubrious and noxious effects in certain circumſtances, explains the nature of animal and vegetable ſubſtances, the formation of volatile alkali, the production of nitrous acid, and the natural proceſs of putrefaction. Various methods are employed for procuring it in a ſeparate ſtate. The moſt uſual proceſs conſiſts in expoſing hepar ſulphuris in a liquid ſtate, to a given quantity of atmoſpheric air under a glaſs veſſel; the liver by degrees abſorbs the oxygen gas, leaving the azotic gas behind. The proceſs of combuſtion, as was ſhewn above, will alſo decompoſe the atmoſpheric air by abſorbing the ſalubrious part, and leaving the noxious portion behind. This accounts for the ſuffocation and death of animals which ſoon follow from burning charcoal or other combuſtible matter in a cloſe room. All writers, until very lately, confounded this fluid with carbonic acid gas; but it is eaſily diſtinguiſhed from it, by being ſpecifically lighter, by having no ſenſible ſmell or taſte, by not changing the colour of vegetable blues, and by occaſioning no precipitation with

with lime water; the reverſe of all which being the properties of carbonic acid gas.

SECT. II.

An explanation of the nature and properties of hydrogen gas.

HYDROGEN gas is a diſcovery of much later date than either of the former; the properties of which it is poſſeſſed, are equally ſingular with thoſe we have already mentioned. It is the lighteſt of all the aeriform fluids, which property hath lately rendered it famous for the conſtruction of air balloons, by the aſſiſtance of which men are poſſeſſed of the power of traverſing, and inveſtigating the ſuperior regions of the atmoſphere, which before ſeemed denied them by nature. According to Cavendiſh, by whom its greateſt rarity was firſt aſcertained in the year 1766, it exceeds common atmoſpheric air in levity in the ratio of twelve to one, which cauſes it continually to tend upwards, and which explains the impurity of the atmoſphere, on high mountains

mountains and other elevations. By itſelf it exſtinguiſhes flame, and kills animals, but in contact with common atmoſpheric air, or oxygen gas, it is highly inflammable; which may be proved by applying a lighted candle to the ſurface of ſtagnant waters, in which animal or vegetable ſubſtances have putrefied after agitation, from which this fluid will immediately take fire, and afford a curious appearance, which clearly explains the nature of that phenonon called ignis fatuus, which is nothing more than hydrogen gas, (produced in the ſame manner and elevated in the atmoſphere), ſet on fire by electricity which continues to burn until the whole is conſumed. To this cauſe ſome have attributed many luminous appearances in the air, ſuch as weak flaſhes of lightning, aurora borealis, and the like; but theſe appear to be more rationally accounted for from electricity alone. But the moſt remarkable properties of which it is poſſeſſed, is, that it conſtitutes one of the component parts of common water, which is proved by exploding fifteen parts of hydrogen gas by the electric ſpark in eighty five parts of oxygen gas,

gas, which it will abſorb during combuſtion, and common water will be produced equal in weight to both gaſes employed. From this cauſe an eminent author conjectures, that thoſe ſhowers which we obſerve to ſucceed thunder and lightning in the ſummer ſeaſon originate. He ſays, "Why may not thoſe ſhowers which are "accompanied with thunder and lightening ariſe from hydrogen gas, exploded "in the ſuperior regions of the atmoſ-"phere by electricity, and therefore chan-"ged into water?" As water is compoſed of hydrogen and oxygen united, all ſubſtances which have a greater attraction with one of theſe two principles of water than they have with each other, will decompoſe this fluid; hence iron and zinc are found to decompoſe water, becauſe theſe bodies have a greater attraction for oxygen gas, than this has for hydrogen gas; conſequently, that which enters into the compoſition of water will ſeparate from the hydrogen gas, and unite with thoſe bodies. This fluid is produced in great quantities from the putrefaction of animal and vegetable

table ſubſtances in ſtagnant water, and from various proceſſes both natural and artificial.

SECT. III.

Remarks on the nature and properties of carbonic acid gas.

THE diſcovery of this fluid is as ancient as Van Helmont, who called it gas ſylveſtris, from its being emitted in large quantities from burning charcoal. But its compoſition and mode of production has been reſerved for the diſcovery of the famous Lavoiſier, who has demonſtrated that it is formed from charcoal, combined with oxygen gas, in the act of combuſtion; from which he has called it carbonic acid, which when fuſed and reduced to an elaſtic aeriform ſtate by combination with caloric, conſtitutes carbonic acid gas, which is ſpecifically heavier than any other permanently elaſtic fluid, being about one-third heavier than common atmoſpheric air, from which it differs in many other properties,

properties, as well as from all other aeriform fluids, to wit, by poſſeſſing the ſpecific property of acids, ſuch as turning vegetable blues red, and being acidulous to the taſte, from which it is reckoned among the number of acid bodies. It renders cauſtic alkalies mild, by combining with them, which clearly explains the cauſe of the efferveſcence produced by their union with acids. It precipitates lime diſſolved in water, by decompoſing the ſolution, by combining with the lime which cauſes it to fall to the bottom. It kills animals, extinguiſhes flame, which explains the cauſe of damps found in ſubterraneous caverns, and it has a conſiderable antiſeptic power, and will check the putrefaction of animal ſubſtances, from which property an eminent phyſician has recommended it very rationally in diſeaſes, of the alimentary canal, tending to putrefaction, by way of gliſter. Laſtly, it is readily abſorbed by water, with which, it forms the mineral waters called acidulous.

After cloſing this ſubject, I cannot lay down my pen without embracing this favourable opportunity of publicly return-

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ing my moſt ſincere thanks to our worthy preceptor, Doctor James Hutchinſon, profeſſor of Chemiſtry and Materia Medica in the Univerſity of Pennſylvania, for the moſt diſintereſted friendſhip and innumerable favours which I experienced from him during my ſtudies in this ſeminary; and of acknowledging the infinite advantages I have received from his ingenious obſervations and accurate experiments, in acquiring the knowledge of thoſe branches which he taught.

FINIS.